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(71) Applicant (*for all designated States except US*): VICTOR HASSELBLAD AB [SE/SE]; P.O. Box 220, S-401 23 Göteborg (SE).

(72) Inventor; and
(75) Inventor/Applicant (*for US only*): DAHL, Ingolf [SE/SE]; Rundbergsgatan 11, S-431 61 Mölndal (SE).

(74) Agents: GRAUDUMS, Valdis et al.; Albihn West AB, P.O. Box 142, S-401 22 Göteborg (SE).

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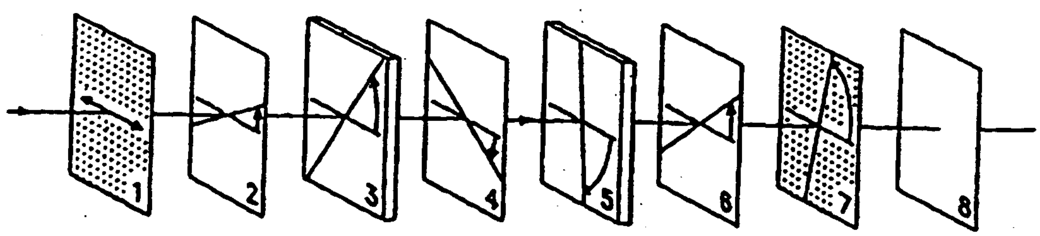

(57) Abstract

A liquid crystal switchable colour filter is described. For electronic photography it can be configured to switch between the colours cyan, magenta, and yellow, to get good properties for colour separation. It could alternatively be configured to switch between the colours red, green, blue and colourless for display purposes, e.g. in field sequential colour displays. The filter consists of a stack of plates, the first and seventh plate being polarizers, the second, fourth, and sixth plate being retarder plates (synonym "phase plates" or "birefringent plates") or groups of retarder plates, the third and fifth being liquid crystal panels (cells), that could be a ferroelectric smectic-C cell in the bookshelf geometry, and the eighth plate being a passive colour filter. The optical properties of this plate combination can be optimised by varying the thicknesses of the components and the angles between the optical directions along the plates.

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TITLE:

Liquid crystal colour filter for electronic photography and for displays.

TECHNICAL FIELD:

This invention relates to colour separation in electronic image-capturing devices, and to the coloration of white light in display apparatuses, by using liquid crystal cells in combination with retarder plates (birefringent plates) and polarizers as a switchable colour filter.

BACKGROUND OF THE INVENTION AND DESCRIPTION OF BACKGROUND ART:

Electronic image-capturing devices are in general not colour sensitive. To get colour images one must place colour filters before the electronic sensor, and to get a full colour picture three different colour filters must be used. One way to achieve this, is to place a fast, electrically controlled colour filter before the sensor, and take a rapid time-sequence of pictures, one for each colour.

Electronic displays could display colours if they can generate a fast time sequence of pictures in the three primary colours. One way to achieve this, is to combine a fast black-and-white display, e.g. a cathode ray tube, with a fast, electrically controlled colour filter in the light path ("field sequential colour display").

Switchable colour filters have been described and patented earlier. The differences from this patent application are

usually according to one or several of the following criteria:

a) Most of them are intended and designed for display purposes only. In that application, the three primary colours or combinations of them are generated by filtering the specific wavelength spectrum of the light-source (GB 2 172 408 A). In electronic image capturing we need to take any light spectrum and analyze in a way that mimics the function of the eye. This is another problem, which requires other solutions.

B) In UK Patent Application GB 2 172 408 A and in European Patent Application 0 138 455 B1 colour selective polarizers are used, sandwiched with liquid crystal cells. Colour selective polarizers polarize the light in a way that depends on the colour. Such a polarizer could for instance transmit horizontally polarized light of one colour and vertically polarized light of another colour. The colour characteristics of such a switchable filter are then mainly determined by the colour properties of these polarizers. In this invention, the colour is generated by the colour dispersion of birefringent plates acting together with the colour dispersion of liquid crystal cells.

c) They use more than two polarizers, which could give higher absorption in the end, and also could increase the thickness of the device.

d) They use polarizers and retarder plates that are oriented in such a way that the angles involved between the various polarizing directions and optical axes always are multiples of 45 degrees.

e) They use twisted nematic cells or nematic pi-cells.

f) They have not optimised the spectral properties, and no optimisation procedure is included in their description.

g) They do not have the same sequence of components as is described in this patent application.

h) They do not transmit the colours cyan, magenta, and yellow.

DISCLOSURE OF INVENTION:

This patent describes the construction of an optimised liquid crystal filter for electronic image capturing and for display purposes. The filter could be switched electrically between three or four different colours. The liquid crystal filter utilises the colour dispersion of birefringent plates together with the colour dispersion of the liquid crystal cells.

The liquid crystal filter consists of a stack of the following elements, illustrated in Fig 1:

1. A colour-neutral polarizing filter plate.
2. A birefringent plate, cut parallel or oblique to the optical axis, or a group of such plates. The birefringent plate should have colour dispersion of the birefringence similar to the "zero-order" type.

3. A liquid-crystal cell or cell combination that optically acts as an electrically changeable birefringent plate. Examples of such cells are ferroelectric smectic-C cells and electroclinic smectic-A cells in the bookshelf geometry, but also various kinds of nematic cells. It is required that we can switch the cell between two optically distinct states.

4. Another birefringent plate, as in point 2 above, but with another thickness and another angular orientation of the optical axis.

5. Another liquid-crystal cell, as in point 3 above, but with another thickness and other angular orientations of the optical axis.

6. Another birefringent plate, as in point 2 and 4 above, but with another thickness and another angular orientation of the optical axis.

7. Another colour-neutral polarizing plate at some angular orientation.

8. A passive colour filter to adjust the sensitivity of the electronic detector for different wavelengths to the sensitivity of the human eye. This filter should thus block ultraviolet and infrared, it the detector is sensitive to that and if the rest of the filter package is transmissive to those wavelengths. It should also remove any strong wavelength dependence of the detector within the visible range.

The two liquid crystal cells have two, electrically controlled optical states each. These states could be denoted "on" and "off". With individual control of each cell we will get totally four optical states for the whole package, which is one state more than we need in applications. Each of the three utilised states is chosen to have a distinct colour. We could, if we want, use a switching sequence

$$\text{off-off} \rightarrow \text{on-off} \rightarrow \text{on-on},$$

without any transition from an "on" state to an "off" state during the imaging sequence. This does not matter too much for smectic cells, but could be important if nematic cells are used.

Some electronic image capturing devices need light shutters for proper operation, while other use electrical gating of the exposure time. A colour filter according to this invention could be combined with a liquid crystal light shutter, and then the light shutter ant the colour filter could share one polarizer. Such light shutters have been described, e.g. in US Patent 3,881,808 and PCT Application PCT/SE90/00109.

All the elements above can have a planar shape, and they can be placed in contact with each other or glued together with their planar surfaces parallel. With this arrangement, we still have the freedom to choose the angular position of all the plates with respect to rotation around an axis normal to the plates. If we measure angles relative to the orientation of the first polarizing plate, we have the freedom to choose the angle of each of the following 6 components, in such a way, that the properties of the filter combination become optimal. Moreover, it is also possible to vary the optical thickness of each of the components 2-6 to get an even better optimisation. We thus have 11 parameters to optimise to get the best colour switching properties of the whole combination. Below it will be shown, that is possible to find proper optimisation functions, in such way that one can let a computer perform the optimisation. With physical data from existing materials, it is also possible to obtain a filter package of adequate quality.

(Optimisation procedure for image capturing devices.)

To get good colour separation in electronic photography, there are two things to optimise. First we want the three optical states of the package to be as transmissible, but still as distinct, as possible. Secondly, we want to avoid irrelevant spectral information affecting the measurements. These requirements could be reformulated mathematically to give us two optimisation criteria. We are then free to choose how to combine these criteria.

The first optimisation criterion ensures that we obtain an adequate colour combination of the three filters, with as good transmission for each filter as possible. In colour filters, commonly used combinations are red-green-blue (RGB) and cyan-magenta-yellow (CMY). For detection, we get better transmission for CMY than for RGB, since the cyan colour means transmission of both blue and green wavelengths, magenta is a combination of blue and red, and yellow is a combination of red and green. It is thus reasonable that an optimisation by computer will give something similar to the CMY combination, and this also is seen in our calculations. The detected signal or image can later be transformed to the RGB representation.

The second optimisation criterion ensures that the detector ignores irrelevant spectral information and that the filter curves do not contain sharp peaks or valleys that enhance some wavelengths and ignore others in an unphysiological way. If the second criterion is not met, we must re-balance the colours afterwards in a subjective way, and in a way that depends of the nature of the object we have been studying. Such a re-balancing could be seen as a somewhat less extreme form of hand-colouring black-and-white pictures.

To describe the optimisation functions in detail it is adequate to use some mathematical concepts. The light that

arrives at one particular pixel element of the detection system contains a lot of spectral information, and the intensity as a function of the wavelength of the light can be described as a vector in a multi-dimensional linear space. The human eye can only extract a small part of this information, and can only determine the position of the colour in a three-dimensional colour space. This colour space is a subspace in the multi-dimensional intensity space. There are well-established physical tables available, that defines the shape of this subspace. The effect of the filter package should thus be to project the multi-dimensional intensity vector on the three dimensional colour space in an adequate way. To each optical state of the filter package we can associate a "filter vector" in the multidimensional intensity space. The components of this vector tell how the different wavelengths are weighted together at the detector. We can divide each filter vector into one part inside the colour subspace, and one part orthogonal to it. The three filter vector parts inside the colour space span a volume, that should be as large as possible. This volume is our first optimisation variable, which should be maximised to give us the first optimisation criterion. This optimisation variable is thus a way to measure the sensitivity of the detection system. Those parts of the filter vectors, which are orthogonal to the colour space, should be as small as possible, and thus the sum of the square of the lengths of these parts will be used as the optimisation variable. Minimising this variable gives us the second optimisation criterion. We can say that this optimisation variable measure the irreversible colour errors of the detection system, since we cannot remove these detection errors by re-balancing the colour, unless we supply additional information about the colours of the picture. One reason to use the sum of the square of the lengths instead of the sum of the lengths is to give the optimisation program smoother functions to work with.

To be a bit more mathematically formal, we can model the action of the eye when it measures the colour and intensity of light. The visual impression of a colour is fully described by three numbers S, Y, and Z, defined by:

$$X = \int \overline{x}(\lambda)\ I(\lambda)\ d\lambda$$

$$Y = \int \overline{y}(\lambda)\ I(\lambda)\ d\lambda$$

$$Z = \int \overline{z}(\lambda)\ I(\lambda)\ d\lambda$$

where $I(\lambda)$ is the intensity of the incoming light, and $\overline{x}(\lambda)$, $\overline{y}(\lambda)$, and $\overline{z}(\lambda)$ are the spectral tristimulus values, defined and tabulated in the CIE 1931 standard colorimetric system (see Publication CIE No. 15 (E-1.3.1) 1971). Usually the integrals are replaced by sums, with tabular values for each fifth nanometre over the visible spectrum of light. An electronic light detector will weight together the light spectrum in a similar way, using a specific weight function $e(\lambda)$, which we could call the sensibility curve of the detector. In the measurement the following integral is evaluated:

$$D = \int e(\lambda)\ I(\lambda)\ d\lambda$$

If we intend to imitate the colour measurements made by the eye, we could design the sensibility of the electronic detector in such a way that it performs three different measurements, using the spectral tristimulus values

$\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ as its sensibility curves. This is unnecessarily restrictive. We could instead use three independent linear combinations of the spectral tristimulus values, and then make a linear transformation to get the three numbers X, Y, and Z. To get the appropriate mathematical framework to optimise the sensibility curves, we introduce a scalar product in the multidimensional intensity space.

$$a \cdot b = \int a(\lambda)\ b(\lambda)\ d\lambda \quad .$$

The measurements made by the eye and by the electronic detector could thus be seen as evaluating scalar products. The spectral tristimulus values $\bar{x}(\lambda)$, $\bar{y}(\lambda)$, and $\bar{z}(\lambda)$ span the "colour space", which is a linear subspace to the intensity space. Using the scalar product, we can, by the Gram-Schmidt orthogonalization procedure, find an orthonormal basis $\hat{x}(\lambda)$, $\hat{y}(\lambda)$, $\hat{z}(\lambda)$ to the colour space. Assume, that our electronic detector has the three filter vectors $e_1(\lambda)$, $e_2(\lambda)$, and $e_3(\lambda)$ as its sensibility curves. We want these filter vectors to be linearly independent, and we should get the best measurements if these spans as large a volume in the colour space as possible. The volume spanned in the colour space by the three filter vectors is given by the absolute value of the determinant of a scalar product matrix

$$V = Abs\left(\begin{vmatrix} e_1 \cdot \hat{x} & e_1 \cdot \hat{y} & e_1 \cdot \hat{z} \\ e_2 \cdot \hat{x} & e_2 \cdot \hat{y} & e_2 \cdot \hat{z} \\ e_3 \cdot \hat{x} & e_3 \cdot \hat{y} & e_3 \cdot \hat{z} \end{vmatrix}\right)$$

We choose this volume as our first optimising variable. Sensibility curves for realistic devices are usually

positive functions, with an amplitude below 1 for any wavelength, and this limits the maximum value of V. With optimal filter vectors very near to be linear combinations of the spectral tristimulus values, it is possible to get a value of V of approximately 42.1. In the design here, we have a polarizer that limits the amplitude to 1/2, and then the optimal value is reduced to one eighth of 42.1, which gives an optimal value of 5.26.

If we had three independent sensibility curves, that were exact and known linear combinations of the spectral tristimulus values, then three measurements would give three exact linear combinations of X, Y, and Z. Then we get an equation system that easily could be solved for X, Y, and Z. A realistic detector cannot easily be designed to have a sensibility curve that is an exact linear combination. We can find how much they deviate from being linear combinations of the spectral tristimulus values by first defining a projection operator P, that projects the sensibility curve into the colour space by

$$P(e) = (e \cdot \hat{x})\,\hat{x} + (e \cdot \hat{y})\,\hat{y} + (e \cdot \hat{z})\,\hat{z}$$

The error in the sensibility curve is then

$$e - P(e) .$$

This is a vector in the intensity space, which is orthogonal to the colour space. It picks up spectral information that the eye ignores, and give an error in the measurement of X, Y, and Z. We can form the second optimisation variable by forming the sum of the square of the lengths of the errors of the three sensibility curves used in the colour measurement:

$$E = (e_1 - P(e_1)) \cdot (e_1 - P(e_1)) + (e_2 - P(e_2)) \cdot (e_2 - P(e_2)) + (e_3 - P(e_3)) \cdot (e_3 - P(e_3))$$

To perform optimisation of a realistic filter, it is important to use realistic values for the wavelength dispersion of the anisotropy of the refractive indices. For this purpose, measurements have been performed on both birefringent plates and a smectic-C cell. As a representative berefringent plate the Polaroid optical retarder of the whole-wave type has been chosen. It is assumed that such retarder plates with outer optical thicknesses are possible to manufacture, and that the colour dispersion is proportional to the optical thickness. The phase difference in degrees between the extra-ordinary and the ordinary light for the Polaroid retarder was measured to

$$11.7 - \frac{5.29 \cdot 10^6}{\lambda^2} + \frac{199600}{\lambda}$$

where the wavelength λ is measured in nm. FLC Optics in Göteborg, Sweden, has supplied a smectic-C cell. The dispersion data of that cell was measured with alignment voltage on, and seems to be quite typical for smectic-C materials:

$$39.3 + \frac{2.805 \cdot 10^7}{\lambda^2} + \frac{13440}{\lambda}$$

For the purpose of the calculation, the polarizers have been assumed to be ideal. The passive filter is assumed to have transmission according to Fig. 2. The detector is assumed to have a flat response curve, giving the same output for the same spectral power at all wavelengths.

To optimise the optical properties of the filter package, the first optimising variable is subtracted from the second, to give a number, that should be as negative as possible. Optimisation requires calculation of a large number of transmission spectra for different values of the variable parameters, and requires some hours of calculation on a PC with 486 processor, using routines written in the language *Mathematica*®. Optimisation by minimising the quantity $E - V$ with respect to the eleven parameters gives transmission curves according to Fig. 3.

The optimised parameters are as follows;
Polarizer 1: Angle 0°;
Plate 2: Angle 15.4°, thickness 0.59 (measured relative to the whole-wave retarder plate);
Cell 3: Angle of optic axis in off position 79.8°, angle in on position 34.8°; thickness 1.00 (measured relative to the FLC Optics cell);
Plate 4: Angle 32.7°, thickness 1.06;
Cell 5: Angle 41.9° in off position, angle in on position -3.1°; thickness 0.67;
Plate 6: Angle 59.9°, thickness 0.46;
Polarizer 7: Angle 164.7°.

This set of parameters gives $V = 4.49$ (optimally 5.26) and $E = 0.433$ (optimally zero). The CIE 1931 chromaticity coordinates {0.186, 0.256} (cyan), {0.332, 0.229} (magenta), and {0.380, 0.530} (yellow). In this context, please note that the chromaticity coordinates do not tell anything about the quality of colour filters intended for colour separation. The chromaticity coordinates tells us how the filters handles the visible information in the light spectra, while the quality depends on how the filter handles such spectral information that we cannot detect with our eyes. The unused fourth position of the filter

(off-on) is almost black with a maximum transmission of 0.03 in red.

Inclusion of real polarizers and filters instead of ideal ones will reduce the value of *V*, but could at the same time also reduce *E*. In the optimisation, specific material parameters have been assumed, but there is no reason to believe that these values are critical for the optical properties of the device. Change of materials of course will require a new optimisation. Some improvements could be expected if the properties of the passive filter also are optimised. Here only normal incidence of light has been studied, but from the thickness of the involved components one could estimate the allowed divergence of the light to $\pm$ 15 degrees around normal incidence. The properties for oblique light could probably be improved by replacing the retarder plates 2, 4 and 6 by groups of retarder plates, eventually combining materials with positive and negative birefringence, as is done in the context of super twist liquid crystal cells (see European Patent Application EP 0 478 383 A2).

As a comparison, we could make a calculation of the optimisation variables for the standard Kodak Wratten filters number 58, 25, and 47B, often used for colour separation. The transmission data is taken from the data sheets. To give a fair comparison and to cut off the infrared transmission of these filters, we also filter the light through the passive filter described above, but assume no polarizer. We then will get a *V* value of 1.88468 and an *E* value of 0.03518. Thus the Kodak Wratten filters give less light through and at the same time larger colour errors.

By a more elaborate calculation, we could also compare the colour errors with those in ordinary photography. For that

purpose, we need a way to measure the irreversible colour error, that is independent of the sensitivity of the measurements. We note that if we include a neutral filter and change the transmission of the filters by a factor of 2, V changes by the factor 8 and E change by the factor 4. This indicates that we could form a relevant measurement of the colour error by forming

$$Q = \sqrt{E}/\sqrt[3]{V}$$

The Q value should be as low as possible, and measures only the irreversible colour errors at the exposure. To get fair measurements, we should also know how to balance the amplitude among the three sensibility functions for each detection system. To make the relative errors equally important, we could normalise the sensitivity function, by requiring that the quadratic norm of the projection of the sensibility function on the colour space should be equal for the three sensibility functions. Then we get the following Q values:

The liquid crystal colour filter according to this invention gives $Q = 0.39$.
The Kodak Wratten filter set gives $Q = 0.78$.
The Kodak Ektachrome 64 Professional film 6117 (Daylight) gives, with data digitised from the spectral sensitivity curves in the data sheets, $Q = 1.94$.

(Optimisation for field sequential colour displays.)

For field sequential colour displays we need to switch among the three primary colours red, green, and blue. One way to do this is to turn the second polarizer 90° from the optimised CMY angle. However, then the liquid crystal

filter is not optimised, and for the parameters given above the "red" colour becomes more yellow than red. The properties could and should be improved by defining new optimisation criteria according to the intended use. For a specific use, one could include the properties of the light source, and adjust the parameters accordingly. To test the possibilities of this invention, we have for this case chosen an optimisation criterion, which is more ad hoc than the criteria for colour detection. The colour gamut of a display is the total range of colours that could be generated by the display. Assume that the transmissions for the three colours are $e_1(\lambda)$, $e_2(\lambda)$, and $e_3(\lambda)$. To get a number characterising the colour gamut, we could calculate the area of all possible colours in a CIE 1960 UCS diagram. This is calculated as the area $A(e_1, e_2, e_3)$ of a triangle in the diagram, with the corner points determined by the three colours of the liquid crystal filter, illuminated by the standard source D_{65}. The true area is not exactly a triangle, but that could not matter to much in the calculation. At the same time, we want as high transmission as possible of each colour. As optimisation variable we have chosen

$$-A(e_1, e_2, e_3)\mathrm{Max}(e_3-e_2-e_3)\mathrm{Max}(e_2-e_1-e_3)\mathrm{Max}(e_3-e_1-e_2)$$

where the Max function takes the maximum value of the argument, calculated for all wavelengths within the visible range. In the optimisation we get several local minima, with somewhat different properties. The following set of parameters gives an interesting minimum:

Polarizer 1: Angle 0°;
Plate 2: Angle 37.1°, thickness 0.43 (measured relative to the whole-wave retarder plate);

Cell 3: Angle of optic axis in off position 107.6°, angle in on position 62.6°; thickness 1.44 (measured relative to the FLC Optics cell);
Plate 4: Angle 36.3°, thickness 1.42;
Cell 5: Angle 14.5° in off position, angle in on position -30.5°, thickness 0.77;
Plate 6: Angle 147.6°, thickness 1.15;
Polarizer 7: Angle 175.5°.
The passive filter 8 is not needed nor used.

This set of parameters gives an optimisation value of -0.001025, and transmission curves according to Fig. 4. The CIE 1931 chromaticity coordinates {*x, y*} for the optimised filters, illuminated by the standard source D_{65}, are {0.538, 0.428} (red), {0.302, 0.561} (green), and {0.188, 0.084} (blue). The fourth filter state is white with coordinates {0.309, 0.317}. In the context of field sequential colour displays, the chromaticity coordinates are highly relevant, since they define the colour gamut. It is possible to tailor the light source to get better colour gamut. By simple blocking light between the wavelengths 473 and 507 nanometres (blue-green) and between 557 and 592 nanometres (yellow), the chromaticity coordinates change to {0.564, 0.389} (red), {0.267, 0.615} (green), {0.197, 0.064} (blue), and {0.301, 0.280} (white).

With patience or a fast computer one can replace the single retarder plates by combinations or retarder plates in the optimisation procedure, and then get more parameters to vary. With more parameters, we could get better colour properties at the cost of increased complexity, absorption and scattering. By simply using two birefringent plates instead of one in the fourth (middle) position in the filter stack, it is possible to decrease the value of optimisation parameter at least to -0.00117, which indicates even better transmission and colour properties.

One interesting point with this construction is that the maximal transmission is only limited by the 50% absorption of the initial polarizer and by the physical imperfections in the involved materials. With reasonable values of these losses, it seems possible to end up with a product that has at least double the transmission of the commercially available colour shutters, using dichroic colour polarizers.

Present state-of-the-art switchable colour filters for full colour control use three or more polarizers, arranged parallel or crossed. To generate the colours, either colour selective polarizers are used, or birefringent plates arranged at 45 degrees' angle to the polarizer axis. It is difficult to generate the colour combination cyan-magenta-yellow with these devices. They thus differ substantially from the present invention, which uses two polarizers and have components arranged at those angular positions that optimise the filter for the specific use. This optimisation gives the invention supreme colour properties and supreme light transmission.

In the invention, each of the elements forming part of the filter stack should be rotated around an axis normal to the plates to a specific angular position, where the properties of the filter combination are calculated to be optimal.

BRIEF DESCRIPTION OF THE DRAWINGS:

Fig. 1 is a schematic view illustrating the construction of a liquid crystal colour filter according to the invention. The numbering of the plates agrees with the numbering in the section "Disclosure of invention". Plate 1 and 7 are thus polarizers, plate 2, 4 and 6 are birefringent plates, plate 3 and 5 are liquid crystal cells, and plate 8 is a

passive colour filter. To get a working filter, angular orientations of the components should be optimised, by rotating the plates around the normal to the plates. The thicknesses of the components should also be optimised.

Fig. 2 shows the transmission of the passive filter as function of the wavelength, as used for the optimisation.

Fig. 3 shows one set of optimised transmission curves for the three optical states of the CMY colour filter, as calculated. This set of transmission curves is optimised for colour separation in electronic image capturing.

Fig. 4 shows one set of optimised transmission curves for the RGB colour filter, as calculated. This set of transmission curves is optimised for displays.

CLAIMS:

1. A liquid crystal colour filter comprising a stack of the following elements:

- a first colour-neutral polarizing filter (1),
- a first birefringent plate (2), cut parallel or oblique to the optical axis, or a plate group of such plates,
- a first liquid-crystal cell (3) or cell combination, electrically switchable between two optical positions,
- a second birefringent plate (4), cut parallel or oblique to the optical axis, or a plate group of such plates,
- a second liquid-crystal cell (5) or cell combination, electrically switchable between two optical positions,
- a third birefringent plate (6), cut parallel or oblique to the optical axis, or a plate group of such plates, and
- a second colour-neutral polarizing filter (7),

c h a r a c t e r i z e d i n that each of said elements (1-7) are rotatably positioned around an axis normal to the elements at respective angular positions, which can be chosen between 0-360°, to optimize the properties of the colour filter.

2. A liquid crystal colour filter according to claim 1, c h a r a c t e r i z e d i n that the liquid crystal cells are ferroelectric smectic-C cells or electroclinic smectic-A cells in the bookshelf geometry.

3. A liquid crystal colour filter according to claim 1 or 2, c h a r a c t e r i z e d i n that the first birefringent plate (2) or plates are uniaxially stretched polymer films or oriented polymeric liquid crystals.

4. A liquid crystal colour filter according to any of the preceding claims, c h a r a c t e r i z e d i n that said stack comprises a passive colour filter (8).

5. A liquid crystal colour filter according to any of the preceding claims, c h a r a c t e r i z e d i n that it comprises both birefringent plates with positive optical anisotropy and birefringent plates with negative optical anisotropy, to obtain better angular properties.

6. A liquid crystal colour filter according to any of the preceding claims, c h a r a c t e r i z e d i n that the thicknesses and the angles of the plates (1-8) are chosen in such a way that it is possible to switch between the colours cyan, magenta and yellow or between the colours red, green and blue.

7. A liquid crystal colour filter according to claim 6, c h a r a c t e r i z e d i n that it is used together with an electronic imaging device to take colour pictures.

8. A liquid crystal colour filter according to claim 7, c h a r a c t e r i z e d i n that it comprises a liquid crystal light shutter.

9. A liquid crystal colour filter according to claim 6, c h a r a c t e r i z e d i n that it is used to generate the colours in a display.

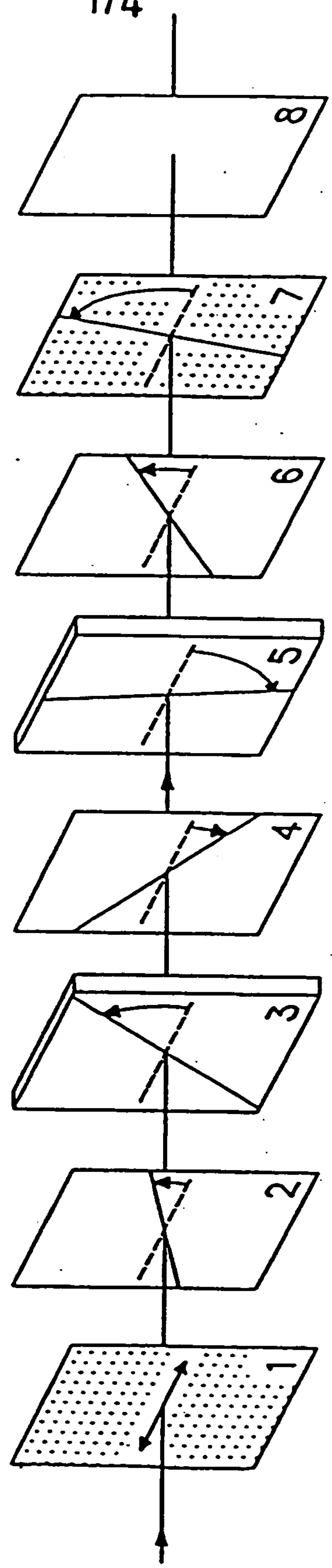

FIG.1

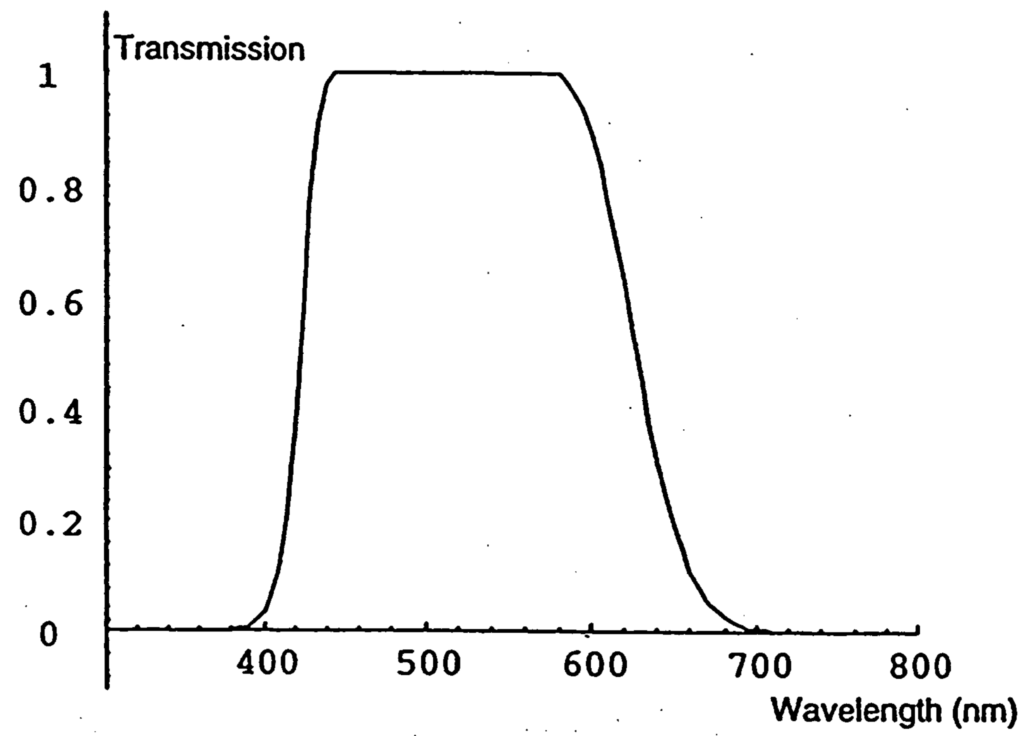

FIG. 2

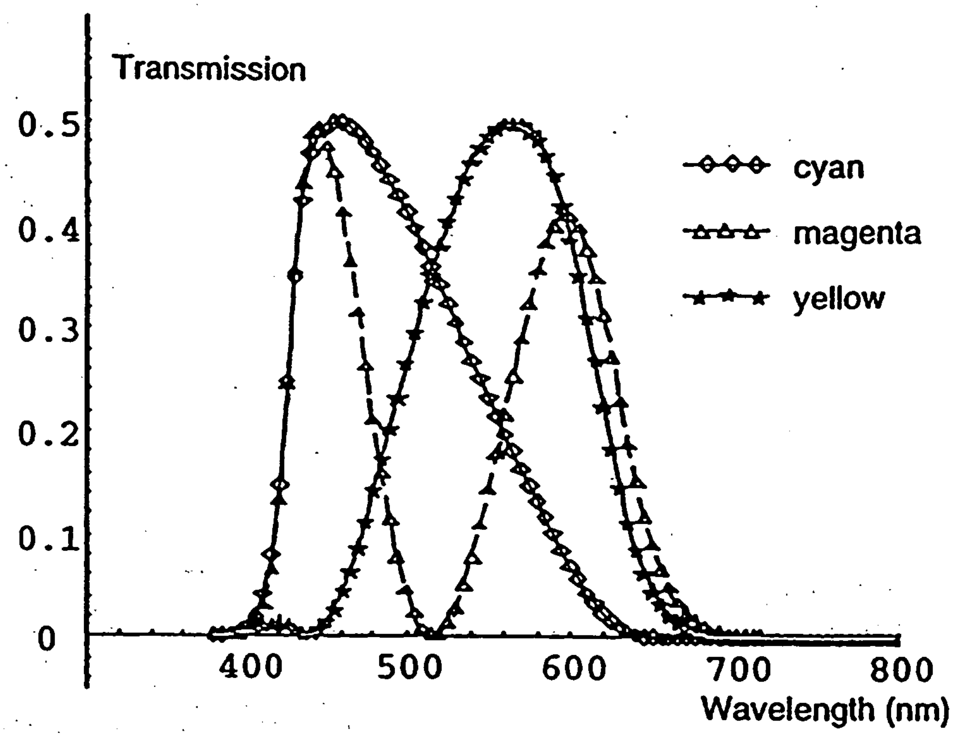
Transmission
0.5
0.4
0.3
0.2
0.1
0
400
500
600
700
800
Wavelength (nm)
cyan
magenta
yellow

FIG. 3

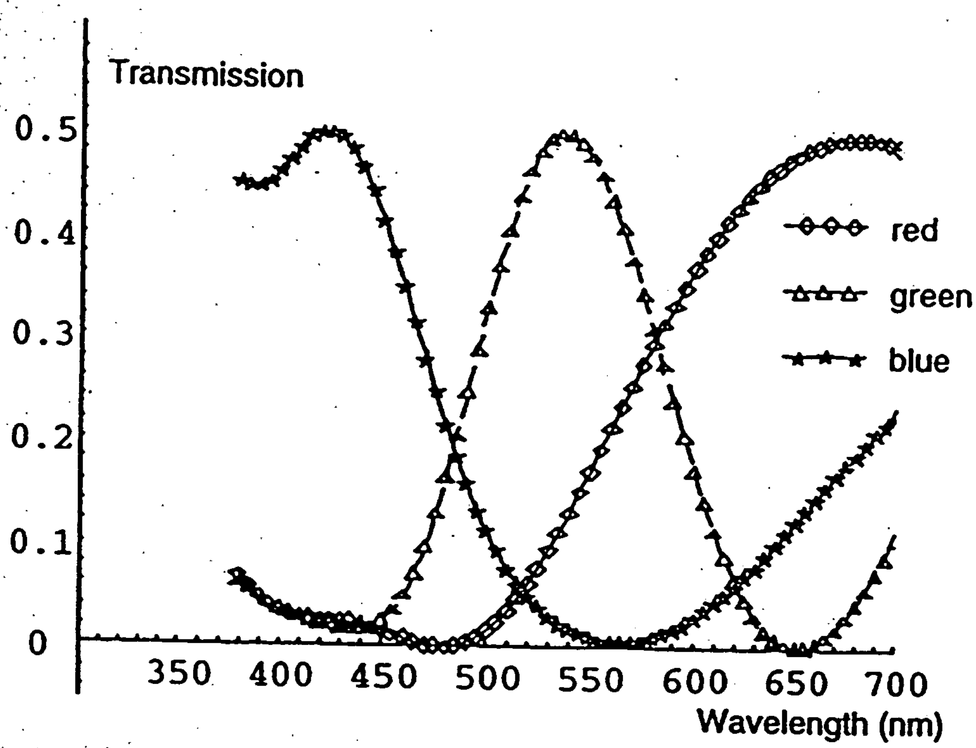
Transmission
0.5
0.4
0.3
0.2
0.1
0
350
400
450
500
550
600
650
700
Wavelength (nm)
red
green
blue

FIG.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 95/01092

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G02F 1/1347, G02B 5/20
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G02B, G02F, H04N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CLAIMS, WPI, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5347378 A (MARK A HANDSCHY ET AL), 13 Sept 1994 (13.09.94), column 4, line 54 - column 5, line 52; column 11, line 50 - column 12, line 42 --	1-7,9
A	WO 9323786 A1 (THE UNIVERSITY OF COLORADO FOUNDATION INC.), 25 November 1993 (25.11.93), page 8, line 1 - page 11, line 20; page 40, line 11 - page 42, line 12; page 63, line 1 - page 73, line 18, figure 9, claim 32 --	1-4,6,7,9
A	EP 0311116 A2 (MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.), 12 April 1989 (12.04.89), abstract --	1

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 March 1996	14 -03- 1996
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bo Gustavsson Telephone No. +46 8 782 25 00

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Journal of Applied Physics, Volume 66, No 10, 1989, (Göteborg), G. Andersson et al, "Device physics of the soft-mode electro-optic effect" page 4983 - page 4995	1-4,6,7,9

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INTERNATIONAL SEARCH REPORT
Information on patent family members

05/02/96

International application No.
PCT/SE 95/01092

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
US-A-	5347378	13/09/94	NONE		
WO-A1-	9323786	25/11/93	NONE		
EP-A2-	0311116	12/04/89	DE-D,T-	3850838	23/02/95
			JP-A-	1271729	30/10/89
			US-A-	4989954	05/02/91
			JP-A-	1097092	14/04/89
			JP-A-	2000828	05/01/90